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ABSTRACT

From 1964-71, 323 pairs of twins and 740 age-matched controls born in 1954-55, were investigated. Compared to schoolchildren in 1880 and 1940 the children in the present study were taller, reached maturity earlier and passed through puberty faster. No differences between socioeconomic strata defined by father's occupation and family income were found either for children's height and weight or for ages at which various criteria of physical maturity were reached. Daughters of manual workers, however, had more weight per height during puberty than did girls of higher status. Children in South Sweden matured half a year later than children in Middle Sweden. The relation between physical and mental development was investigated by comparing the mental performance of physically early, average and late maturing girls and boys from grade 3 through 7. Support for analogous spurts in physical and mental growth was found. Social background played a more important role than physical maturity for the children's performance on various achievement and mental ability tests given in grades 3, 5, and 6. Measures of mental performance were the Standard Achievement Test in Swedish and in Mathematics: Differential Ability Test: Intellectual Capacity Test: and grades. (Author/CP)

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Studies in Education and Psychology 5

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Physical and Mental Development in Swedish Urban Schoolchildren

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Abstract

Swedish urban schoolchildren were followed longitudinally for a study of their physical and mental development during the period 1964–1974. The purpose of the thesis is to summarize and discuss the findings, originally reported in five separate papers, which are included in the supplement. Compared to the physical growth and development of schoolchildren in 1880 and 1940 the children in the present study were taller, reached maturity earlier and passed through the whole process of puberty at a higher speed. No differences between socio-economic strata defined by father's occupation and family income were found either for children's height and weight or for ages at which various criteria of physical maturity were reached. Girls in social group III, however, had more weight for height during puberty than had girls in social group I and II.

Children in the South of Sweden matured half a year later than children in Middle Sweden.

The relation between physical and mental development was investigated by comparing the mental performance of physically early, average and late maturing girls and boys from grade 3 through grade 7. Certain support for analogous spurts in physical and mental growth was found. Social background played a more important role than physical maturity for the children's performance on various achievement and mental ability tests given in grades 3, 5 and 8.

In some of the tests early maturers scored higher than late maturers within social group III while no such differences between early and late maturers were found within social group I and II. This was found mainly for verbal achievement and was more pronounced for girls than for boys.

Gunilla Westin-Lindgren

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(I) Ljung, B.-O., Bergsten-Brucefors, A., and Lindgren, G.: The secular trend in physical growth in Sweden. *Annals of Human Biology, 1,* 245 - 256, 1974.

(II) Lindgren, G.: Height, weight and menarche in Swedish urban schoolchildren in relation to socio-economic and regional factors. *Annals of Human Biology, 3,* 501 - 528, 1976.

(III) Lindgren, G.: Growth of schoolchildren with early, average and late ages of peak height velocity. *Annals of Human Biology, 5,* 253 - 267, 1978.

(IV) Lindgren, G.: Peak velocities in height and mental performance. A longitudinal study of schoolchildren aged 10 - 14 years. Accepted for publication in *Annals of Human Biology,* 1979.

(V) Lindgren, G.: Achievement and mental ability of physically late and early maturing schoolchildren related to their social background. Submitted to *Journal of Child Psychology and Psychiatry,* 1979.

These publications will be referred to by the above Roman numerals. Other relevant reports and papers by the present author which are referred to in the text will be found in the list of references.

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1. INTRODUCTION

In the mid-1960's a longitudinal study of the physical and mental growth and development in twins and singleton controls of the age period 9 - 17 years was initiated by the late Professor Yngve Norinder. The investigation called the SLU-project was planned and carried out at the Stockholm Institute of Education (formerly the School of Education), Department of Educational Research and was financed by the National Swedish Board of Education. The general background, the motives and the plans for the study have been given by Norinder (1964). An overview of the whole study has also been reported by Brucefors (1972).

The two principal objectives of the project were to study

- the influence of genetic and environmental factors on physical and mental development by means of the twins and their matched controls and
- the physical development and its relationship to mental development in the group of singleton controls.

Studies according to the former objective have been summarized and discussed by Fischbein (1979). The latter objective is dealt with in the present summary.

2. BACKGROUND OF THE PRESENT STUDY

In the memorandum which formed the basis of the SLU-project, Norinder (1971) referring to Tanner drew attention, amongst other things, to the phenomenon called the secular trend in physical growth of children and young adults, thus pointing at the neccessity of studying the physical growth of a representative and contemporary sample of growing children.

> "In Sweden and elsewhere these (retrospective anthropometric investigations) show that successive generations, except for times of war and depression, have on the average speeded up their physical growth." (op.cit., p. 5)

The standards of height and weight for children from 10 years which were generally used by the school health service were based on data from a cross-sectional study conducted in 1938 - 39 by Broman, Dahlberg and Lichtenstein (1942). Therefore one of the aims of the SLU-project was to provide contemporary height and weight data for construction of new standards. According to Tanner, Whitehouse and Takaishi (1966, p. 454) such revisions should be done every tenth or fifteenth year until this secular trend has stopped.

The causes of the trend are supposed to be multiple although a general improved standard of living conditions - especially better nutrition - seems to be a major factor (Tanner, 1962, p. 152 - 153). A diminishing disparity in standards of living between different socio-economic strata may equally have contributed to an increasing equality in growth rate between different socio-economic classes (Degnbol, 1964). With regard to the increase in adult height a genetical population-movement hypothesis has also been stressed (Broman et. al., 1942, p. 7 - 10).

About the further implications of this secular trend in physical growth Norinder quotes Tanner (1961):

> "the secular trend, both in earlier maturation and in greater size, is one of the most considerable phenomena of human biology at present, and has, into the bargain, a host of medical, educational and sociological consequences." (op.cit., p. 119)

According to some researchers social consequences of the secular trend in physical growth are a decrease in chronological ages when youth are allowed to vote, to have sexual intercourse and to marry (for references see Lindgren, 1975, p. 6).

In contrast to this the time spent at school has been expanded thus in a way prolonging the childhood period with pedagogical problems as possible consequences (Husén, 1979). From 1962 the Swedish comprehensive school age was extended to last from 7 to 16 years. Socio-medical problems have also been pointed out, such as the increase of venereal diseases, abortions and misuse of alcohol and drugs in successively lower age groups.

Apart from the social and medical aspects several researchers (e.g. Tanner 1961, 1962; Muuss, 1970) have speculated about a relationship between the parallel secular trends in physical and mental development. Comparisons have been made between similar groups of children or young adults during different periods of time and even if not always expected, an increase in mental ability has been detected. For an overview of investigations made on this topic in England, Scotland, U.S.A., France and Sweden, see Husén (1974, p. 58 - 80). From the Scottish surveys conducted in 1932 and 1947 Husén states:

> "Indeed, height over the years 'behaved' almost the same as IQ; that is, there was a low negative correlation between height and family size, but there was a marked increase in standing height from 1932 to 1947 (something which, by the way, has been observed in all countries, where representative data for successive age groups of schoolchildren or military inductees have been available)." (op.cit., p. 70)

and concludes:

> "Considering our present knowledge a decline in mean intellectual performance is not in sight, on the contrary it seems to rise." (op.cit., p. 80)

In Sweden as late as in the 60's Stahle (1973) found an increase of mental ability in 13 year olds during such a short period as five years from 1961 to 1966.

If this general increase in mental ability occurs it is difficult to tell, *how* it is actually connected to the accelerated physical growth, since the investigations have had to be conducted independantly of each other. The increase of mental ability could as well be an effect of invironmental factors only, as e.g. Muuss (1970) has stated:

> "To what extent changes in the patterns of physical development and changes in mental test scores are interrelated is hard to assess since increasing school attendance, better education and the mass media of communication and even increased exposure to and experience with testing would most likely contribute to increased intelligence test scores." (op.cit., p. 279)

Results from an ecological analysis by Härnqvist and Stahle (1977) support this environmental explanation. They found that the increase in average test scores in mental ability for two comparable samples of Swedish 13 year olds "occurred simultaneously with several changes in social and educational conditions".

The relationship between physical and mental development has also been asserted because of the sex differences found in school achievement, mental ability and other overt behaviour during puberty. The hypothesis has been that as girls become physically mature about two years earlier than boys they will also be superior to boys in school achievement and mental ability as well as socially behave more maturely than boys during this period (for references see Lindgren, 1975, p. 6 - 8).

However, the sex differences do not always point in the same direction and the results found for boys and girls in different subjects and behaviours are contradictory (Maccoby and Jacklin, 1974). Anastasi (1958) warns against making interpretations which claim that sex differences in general are solely the effects of biological differences.

> "From all that has been said, it is apparent that we cannot speak of inferiority and superiority, but only of *specific differences* in aptitudes or personality between the sexes. These differences are largely the result of *cultural and other experiential factors*, although certain physical sex differences undoubtedly influence behavior development, either directly or through their social effects. Lastly, the overlapping in all psychological characteristics is such that we need to consider men and women as *individuals*, rather than in terms of group stereotypes." (op.cit., p. 497 - 498)

Husén (1974) referring to Maccoby and Jacklin states that:

> "When it comes to specialized abilities, such as the spatial and the verbal, there appears to be some interaction between sex-linked genetic factors and socio-cultural factors." (op.cit., p. 134 - 135)

Ljung (1965) found evidence for a mental growth spurt analogous to the physical growth spurt - at least for girls. With regard to the sex differences in mean gain on the verbal comprehension fac-

tor he claimed:

> "The findings are in agreement with the observation that boys are on the average late maturers as compared with girls in the verbal comprehension factor (see below). Studies of physical growth have shown that the intensity of the spurt is related to the general rate of maturation. This seems to apply to mental growth, too." (op.cit., p. 255)

The association between spurts in human brain growth and mental growth spurts has lately also been hypothesized by Epstein (1974) after having analyzed data from about 20 independent studies. Mental spurt periods occurred at the age periods 2 - 4, 6 - 8, 10 - 12 and 14 - 16 years and an especially low rate of mental growth at 12 - 14 years.

> "These ages correlate very well with those found for spurts in brain and skull sizes so that an obvious working hypothesis is that mutations for increased brain weight were selected for by virtue of the greater mental ability thus afforded to humans." (op.cit., p. 217)

More directly the relationship between physical and mental development has been studied by comparing mental test scores of children and youth in relation to their physical growth and maturation (Abernethy, 1936; Freeman and Flory, 1937; Shuttleworth, 1939; Boas, 1941; Nisbeth and Illsley, 1963; Douglas and Ross, 1964; Johannesson, 1974; Kohen-Raz, 1974).

Douglas and Ross (1964) in their British longitudinal study of 5 000 girls and boys found that physically early maturers were superior to late maturers on tests measuring school achievement. Even when social background was controlled for this difference persisted - but mainly for the girls. For boys certain social group differences were found.

> "... there is little difference in ability or performance between adolescent and preadolescent boys in the upper middle class, although there is an increasing difference in passing through the lower middle to the lower manual working class for the boys. *This suggests that there is a cultural element associated with the superior ability of the early maturers and that one is not solely concerned with a biological relationship between accelerated mental and sexual development, at any rate for the boys.*" (op.cit. p. 195, my italics)

In this British investigation no mental spurt anlogous to the physical spurt was detected which, however, might in part be due to the relatively few measurements, for these were taken at 6, 7, 11 and 15 years of age only during the investigation period. The early maturers - girls as well as boys - seemed to stay longer at school. A possible explanation could be that the early maturers, because of their higher test results in lower ages, were thereby encouraged and more motivated to continue their formal education.

This the hypothesized relationship between physical and mental development has been based on investigations with independent samples by comparing parallel secular trends in physical and mental growth and also by comparing sex differences in achievement and mental ability during puberty. On an individual basis the relationship has been studied by comparing scores of individuals of the same age and sex but of varying physical maturity level defined by various criteria on physical maturity.

3. PURPOSE AND MAIN RESEARCH QUESTIONS

The principle objective of the SLU-project: *to study the physical development and its relationship to mental development in a contemporary sample of Swedish schoolchildren* has been worked with stepwise. Firstly by splitting the objective into:

(A) a description of the physical development of the children and
(B) a study of some relationships between physical and mental development of these children.

Secondly by working with this twofold purpose according to successive main questions within a research paradigm illustrated in Figure 1.

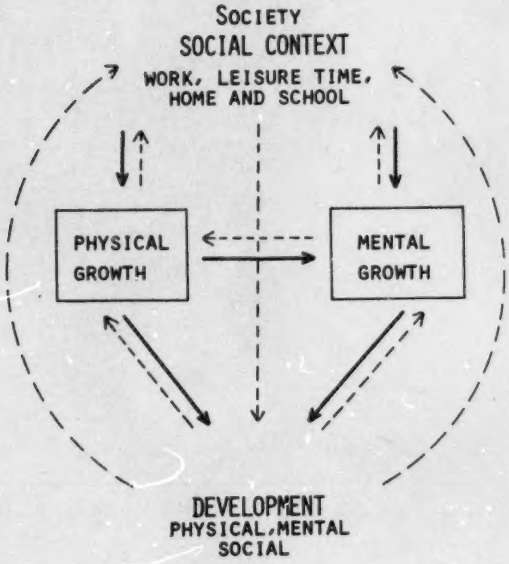

Figure 1. A research paradigm.

The research paradigm resembles the one used by Ljung (1965, p. 28). The definitions of growth and development are adopted from Ljung, (1965, p. 27) and Tanner (1978).

> *"Growth is a product of the continuous and complex interaction of heredity and environment. ..., what is inherited is DNA. Everything else is developed.* We may write $G^{*}E \xrightarrow{time}$ (GE) where G stands for genetic and E for environmental factors. The product (GE) develops through time, and the way G and E are related is shown by a star, not a plus sign nor even a multiplication. We say that the interaction of genetics and environment is non-linear, meaning that the effects do not in general sum (as would be indicated by a plus sign)." (op.cit., p. 117; my italics)

According to Ljung (1965, p. 27) *physical growth* is defined by the structural and functional changes taking place in different bodily dimensions; and *mental growth* by change in overt behaviour e.g. changing scores on mental ability tests. Rate of growth or rather *tempo of growth* (this concept once coined by Franz

Boas according to Tanner 1978, p. 78) is defined by change per unit of time.

The hypothesized relation between the two aspects of growth is that *mental growth is in part a function of the physiological correlates of physical growth.*

Physical and mental development (as well as social development) takes place in a social context which is comprised of different environmental or social elements that interact with the growing individual. The social elements are to be found in the society or more specifically in the home, at school, at work and during leisure time.

Due to the twofold purpose the successive questions for research have been raised within the paradigm in the following order:

Question A:1 What is the physical development of this sample of schoolchildren?

In the paradigm the answer to this question is to be found by describing the physical growth and development of the samples of girls and boys under study (Lindgren, 1975). A summary of this description is given on p. 21 - 34.

A subsequent question was then:

A:2 Were these children maturing more rapidly than children of previous generations?

The answer to this question was sought by comparing the physical development of the children under study with previous studies reported in 1885 and 1942 (Paper I). This comparison would need a three-dimensional illustration in the paradigm.

It was claimed that one of the major causes of the secular trend probably was better standard of living (including nutrition and health care) and maybe also a higher urbanization level (with more out-breeding) so the answer to the following question was also of great interest:

A:3 Was these children's physical development related to socio-economic and regional factors?

This question was studied by relating the children's physical growth and development to the socio-economic status of the child (defined by father's occupation and family income) and to geographical area or urbanization level (number of inhabitants) in which the children were brought up. The relations are illustrated in the paradigm by the arrows from elements in the social context to physical growth and to physical development. The results from the study of these relationships are given in paper II.

Before studying the relationship between physical and mental development the next question was put:

A:4 What were the physical characteristics of early, average and late developers or maturers?

The terms early, average and late maturer have a somewhat different meaning depending on the criterion of physical maturity chosen. The most reliable measure on physical maturity for the present sample was the age at which maximum growth in height (PHV age) occurred. This criterion was also applicable to both sexes. So another description of the physical growth and development was asked for - this time in order to describe the differences in physical growth and development between early, average and late maturers (defined by PHV age). The study of these differences is reported in paper III. Finally the following general question was put forward:

Question B Were there any relationships between the physical and mental development of these children?

From the general question above the more specific questions were extracted:

B:1 Was there a spurt in mental growth analogous to the spurt in physical growth during puberty?

8:2 Were physically early maturers in general superior to late maturers in school achievement and mental ability at the investigated ages?

The last questions were studied by relating the physical growth and development to mental growth and development. However, a child's mental development is also influenced by elements in the social context and especially the relation to social background (defined by father's occupation; in the paradigm symbolized by home) was considered. The findings from the latter studies are reported in papers IV and V.

4. MATERIALS AND METHODS

The total SLU-sample includes two main groups. One group consists of pairs of twins, the other of one or two classmates to the twins - of the same sex, born in the same month and year (mostly in 1955, a few in 1954) as the twins they were to match (see Norinder, 1971; Ljung, Fischbein and Lindgren, 1977). The samples were drawn from urban elementary schools where the possibilities of making uniform arrangements for the different tests and observations were supposed to be better than in rural schools. When the sampling procedure started in 1964 it was neccessary to contact the school authorities in about 40 towns and cities to find at least 300 twin pairs for the study (Norinder, 1971, p. 6). Thus altogether 323 pairs of twins, which was approximately 30 per cent of the total twin population born in Sweden in 1955, and 1 193 matched controls were sampled for the study.

4.1 The sample

For the purpose of studying the physical growth and development of the controls or singleton classmates only those individuals with two or fewer physical measurements missing during the investigation period were included. According to Norinder (1971, p. 6 - 7) the pupils managed to spread from the 40 local authorities to about 60 during the period 1964 - 1971. This fact has made it difficult to maintain uninterrupted contact with them thus decreasing the sample of singleton classmates in the longitudinal analysis to about 62 per cent (64 % for the boys and

60 % for the girls) of the original sample. This group of 740 pupils (380 boys and 360 girls) is referred to as *the core sample*. An analysis of the withdrawals (the remaining 38 %) concerning height and weight measurements was, however, performed. The results of this analysis are reported in section 4.3 (p.17).

The core sample is not representative for the country as a whole but it represents urban children well and is 1.4 per cent of the total population of live born children in urban areas in 1954/55. The distribution of the pupils in the core sample according to the different towns and cities has previously been described by Lindgren (1973, p. 11 - 15) where it was also shown that in 1971 the distribution of pupils due to urbanization level (number of inhabitants) was similar to the distribution for the original sample. The distribution of the pupils' birthmonths does not deviate from the distribution for the total population of children born in 1954 or 1955 as has been shown by Lindgren (1973, p. 13).

The representativeness of the core sample concerning the social group distribution is good since the distribution agrees well with the one reported by Otto (1976, p. 48) regarding an annual population of urban conscripts born in 1953.

4.2 Data collection, instruments and methods

The pupils had experienced 20 - 40 measurements of various sorts from the spring term in grade 3 (1965) to the spring term in grade 9 (1971) inclusive. The measurements which will mainly be referred to in this summary are shown in Table 1.

Measurements of physical characteristics; height, weight and observations of the development of secondary sex characters (SSC) have been carried out twice a year by school nurses. At once they asked the girls *if* and in that case *when* they had experienced their menarche. Additional measurements were taken on the boys both in grade 10 (secondary education; grade 1 in Sw. gymnasieskolan) and when enrolled in military service in 1972/74 at the age of 17 - 19 years. These additional measurements were collected as some of the boys at the end of grade 9 had not yet completed their height development. For descriptions of the measurement

procedures on the physical development; at school see Lindgren (1973, 1975) and papers I and II; at the enrolment of the military service see Aronsson and Lindgren (1979; Appendix).

The main criterion used for children's physical maturity is age at maximum gain in height (cm/year) or peak height velocity age (PHV age). The method which has been used to estimate PHV age as well as the methods of estimating ages at which other criteria on physical maturity were reached for each individual are described by Lindgren (1975) and in paper II (p. 502 - 503).

Year		64 - 65	65 - 66	66 - 67	67 - 68	68 - 69	69 - 70	70 - 71	71 - 72	72 - 74
Grade		3	4	5	6	7	8	9	1 10	Conscript data
Age (years)		9 - 10	10 - 11	11 - 12	12 - 13	13 - 14	14 - 15	15 - 16	16 - 17	17 - 19
Measurements in physical characteristics	Height	○●	○●	○●	○●	○●	○●	○●	●	●
	Weight	○●	○●	○●	○●	○●	○●	○●	●	●
	SSC	○●	○●	○●	○●	○●	○●	○●	●	
Measurements in school achievement and mental ability	KUP-test	○●	○●	○●	○●	○●				
	Sw	●								
	Ma	○●			○					
	DBA-test			○						
	Mark(Sw,Eng,Ma)				○					
	IC-test									

○ girls
● boys

Table 1. Measurements conducted during the investigation period 1965 - 1974.

Measurements in school achievement and mental ability were conducted in the grades and at the ages shown in Table 1. The KUP-test has been thoroughly described in paper IV. Achievement tests in Swedish (Sw_3) and Mathematics (Ma_3, Ma_6) as well as the mental ability test (DBA_5) and Marks in Swedish, English and Mathematics ($Mark_{Sw, Eng, Ma,}$) have been described in paper V.

Certain background variables have been used in some of the analyses; such as the pupils' socio-economic background and the urban/regional area from which the pupils were sampled. These variables are described in paper II (p. 504 - 505).

In the general discussion of the present summary some conscript

data are also referred to concerning the boys' scores on an intelligence test (Intellectual Capacity) and their length of formal education.

The Intellectual Capacity test (IC-test) consists of 4 subtests (Logical reasoning, Verbal ability, Spatial ability and Technical understanding). A composite score (stanine) of the four subtests has been used in the present study (cf. Otto, 1976).

The boys were grouped into four categories according to length of formal education (from the Swedish Standard Classification of Education,1969).

1. Compulsory comprehensive school (Sw. Grundskola $\leq$ 9 years)
2. Upper secondary school or continuation school (Sw. Fackskola or gymnasial utbildning $\leq$ 2 years)
3. Upper secondary school or senior high school (Sw. Gymnasial utbildning $\geq$ 2 years)
4. University level college and university (Sw. Eftergymnasial utbildning; högskola or universitet).

The categories 3 and 4 were combined as there were not many young men who at the time of the enrolment had started university training because of their chronological age (17 - 19 years).

The various statistical methods used in analyzing the physical and mental data are separately reported in the respective papers I - V.

4.3 Withdrawals

Approximately 40 % of the girls and 36 % of the boys from the original sample of controls were excluded from the core sample when studying the physical growth of the children mainly because they did not have height and weight measurements covering the whole investigation period - a necessity for estimating PHV age and PWV age (peak weight velocity age).

Most of these withdrawals had, however, two or more measurements

in height and weight with a maximum of one year intervals between two successive measurements which made it possible to interpolate height and weight data to certain exact ages (10.0 years, 10.5 years etc). Thus out of these 40 % of girls and 36 % of boys interpolated values for height and weight at various ages have been estimated for 34 % and 31 % respectively so as to compare with the values estimated for the core sample. 66 individuals (or 5.5 % of the original sample of controls) were not included in these data computations since they had less than two measurements *or* bigger intervals than one year between successive measurements (see Table 2).

	Girls		Boys		Total	
	n	%	n	%	n	%
Original sample of controls	595	100	598	100	1193	100
Core sample	360	60.5	380	63.5	740	62
All withdrawals	235	39.5	218	36.5	453	38
One measurement only *or* two with big intervals between measurements	33	5.5	33	5.5	66	5.5
Rest of withdrawals	202	33.9	185	30.9	387	32.4

Table 2. Number and per cent of individuals in the core sample and the group of withdrawals respectively.

Heights and weights for each half year (10.0 - 16.0 years for girls and 10.0 - 18.0 years for boys) have been estimated for the *rest of withdrawals* and compared to those for the *core sample*. The differences in mean height (as well as mean weight) between the two groups have been tested (t-test) at all ages (Lindgren, 1979). At the age of 11.0 years and for girls only the mean weights differed significantly ($p < 0.05$).

It has been claimed by Taranger (1976, p. 21) that the core sample of girls might be selected since the standard deviations

for height at various ages were smaller compared to other studies. A comparison of variances in height at all ages between the study of Taranger's and the present study gave, however, only one statistically significant d fference. The core sample and the withdrawals in the present study were combined and means and SD:s were thus estimated in height and weight at different ages for at most 557 girls (at 12.0 years of age) and approximately 558 boys (at 12.0 years of age). The SD:s in height at various ages for girls became somewhat greater but did not exceed the SD:s reported from the study of Taranger's (1976) comprising about 80 girls. For boys the SD:s remained the same.

The best values for estimating standards in height and weight at different ages would be those for the core sample and the withdrawals combined. These values are given as means and SD:s as well as centiles in Table 4 and 5 (p. 22 - 25). The centiles are estimated from rawdata and the values at the extreme ends of the distributions (eg. the 3rd and the 97th centiles) will be better estimated by the increased number of individuals (cf. Healy, 1974). The centiles for height and weight at all ages are also illustrated in the diagrams given in Figures 2 - 5 (p. 26 - 29). The model for the diagrams comes from Tanner et al. (1966).

A comparison of the social group distributions for the original samples of twins and controls as well as the core sample and the withdrawals has been made (see Table 3).

The social group distributions of the core sample and the withdrawals differ somewhat in that social group II seems underrepresented among the withdrawals - especially for the boys. Boys from social group II will probably be found in the group of "unknowns".

Out of the 66 individuals which were not included in the group of withdrawals (p. 18) among the boys 5 belonged to social group II, 5 to social group III and 23 were of unknown social group; among the girls 9 belonged to social group II and 24 were of unknown social group. Differences in mean heights and weights between social groups in the group of withdrawals have been tested for the ages at which the maximum number of individuals

had height and weight measurements. None of the tested differences were significant. Thus the results given in paper II about the non-significant differences in height and weight between social groups are confirmed (Lindgren, 1979).

The representativeness of the core sample in the analyses of other variables like the KUP-test and various achievement and mental ability tests is separately discussed in papers IV and V.

	Social group			
	I	II	III	Unknown
Twins				
Girls (n=320)	17	40	40	3
Boys (n=326)	17	36	44	3
Original sample of controls				
Girls (n=595)	14	36	39	11
Boys (n=593)	15	36	38	11
Core sample				
Girls (n=360)	15	38	41	6
Boys (n=380)	14	40	41	6
All withdrawals				
Girls (n=235)	13	32	36	19
Boys (n=218)	17	30	34	19
Rest of withdrawals				
Girls (n=202)	15	35	40	10
Boys (n= 185)	19	30	41	10

Table 3. Social group distributions (per cent) for the original samples of twins and controls as well as for the core sample and the withdrawals.

5. SUMMARY OF RESULTS

5.1 The physical development of girls and boys. (Question A:1, Lindgren, 1975)

The development of the children's height and weight at successive ages (girls 10.0 - 16.0 years; boys 10.0 - 18.0 years) is given in Tables 4 - 5 (p. 22 - 25) and in Figures 2 - 5 (p. 26 - 29).

In the tables are reported:Means (arithmetic means), SE:s (standard errors) and SD:s (standard deviations). Estimated from rawdata the 3rd, 10th, 25th, 50th, (median), 75th, 90th and the 97th centiles (or percentiles) are also given. With regard to heights at different ages a more precise method of estimating the centiles would have been to calculate them directly from the means and SD:s, since for height (in contrast to weight) Gaussian distributions can be assumed. This calculation can, however, quite easily be made from the means and SD:s in Table 4 and 5 (cf. Tanner et al., 1966, p. 45b).

The means (and medians) given in Table 4 and 5 are practically the same as reported by Lindgren (1973, 1975) except for the boys' mean heights and weights at the ages 16.0 - 17.0 years. These values were corrected after having received conscript data on the height and the weight for the boys at the age 17.4 - 19.7 years (see paper II, p. 515). The height and weight values for girls aged 16.0 years might be biased because of the comparatively smaller number of individuals at this particular age.

HEIGHT (cm)

Age (years)	No. of girls	Mean	SE	SD	centiles 3rd	10th	25th	50th	75th	90th	97th
10.0	199	139.9	0.44	6.2	128.6	131.3	135.2	140.3	144.3	147.7	150.9
10.5	468	142.6	0.30	6.5	131.0	134.0	138.0	142.4	146.9	150.8	155.1
11.0	542	145.8	0.30	6.9	133.8	136.5	140.8	145.7	150.4	154.4	159.2
11.5	557	149.2	0.30	7.1	136.2	139.9	144.0	148.9	154.1	158.4	163.2
12.0	557	152.6	0.30	7.1	139.1	143.5	147.6	152.5	157.8	161.8	166.1
12.5	553	155.8	0.30	7.0	141.9	146.2	151.0	155.7	160.9	164.2	169.1
13.0	545	158.5	0.29	6.6	144.9	149.2	153.9	158.6	163.2	166.8	170.5
13.5	530	160.5	0.28	6.4	147.7	152.1	156.0	160.6	165.0	168.0	171.5
14.0	512	162.3	0.27	6.1	150.1	154.3	158.0	162.7	166.5	169.8	173.1
14.5	495	163.7	0.26	5.8	152.3	156.0	159.4	164.0	167.8	171.0	174.1
15.0	466	164.5	0.26	5.7	153.7	156.8	160.8	164.7	168.5	171.9	174.4
15.5	389	164.9	0.29	5.7	154.1	157.4	161.0	165.0	169.0	172.8	175.2
16.0	160	165.7	0.44	5.6	155.0	158.0	162.0	166.0	169.0	173.0	175.8

WEIGHT (kg)

Age (years)	No. of girls	Mean	SE	SD	centiles 3rd	10th	25th	50th	75th	90th	97th
10.0	199	32.2	0.41	5.8	23.0	25.3	27.8	31.7	35.4	39.7	43.6
10.5	468	34.0	0.29	6.3	24.9	27.0	29.5	33.1	37.2	41.7	48.4
11.0	542	36.4	0.30	7.1	26.0	28.4	31.3	35.5	40.1	45.8	51.7
11.5	557	38.7	0.32	7.5	27.7	30.0	33.2	37.9	42.9	48.9	55.4
12.0	557	41.2	0.34	7.9	29.2	31.9	35.4	40.2	46.0	51.1	58.7
12.5	553	43.8	0.35	8.2	31.4	34.4	37.8	43.0	48.5	54.0	61.9
13.0	545	46.2	0.35	8.2	33.3	36.5	40.3	45.5	50.5	56.4	63.6
13.5	530	48.2	0.36	8.2	35.2	38.6	42.4	47.5	52.3	58.2	65.0
14.0	512	49.7	0.34	7.7	37.3	41.0	44.4	48.9	54.0	58.9	66.1
14.5	495	51.2	0.34	7.4	39.5	42.8	46.1	50.4	55.2	60.0	68.0
15.0	466	52.4	0.35	7.5	40.7	44.2	47.4	51.6	56.3	61.3	69.0
15.5	389	53.5	0.39	7.8	41.1	45.3	48.5	52.3	57.5	62.6	70.9
16.0	160	54.3	0.61	7.7	42.5	46.1	48.9	53.5	57.6	53.2	71.3

Table 4. Standards for girls. Height (cm) and weight (kg) from 10.0 - 16.0 years of age.

HEIGHT (cm)

Age (years)	No. of boys	Mean	SE	SD	centiles 3rd	10th	25th	50th	75th	90th	97th
10.0	217	140.0	0.40	5.8	130.2	132.0	135.5	140.1	144.3	147.8	150.4
10.5	479	142.1	0.27	5.9	131.3	134.5	138.3	142.0	146.3	149.7	153.5
11.0	542	144.7	0.26	6.1	133.1	136.7	140.4	144.8	148.8	152.2	156.3
11.5	556	147.3	0.27	6.4	135.1	139.1	143.0	147.2	151.5	155.6	159.8
12.0	558	149.9	0.29	6.9	137.5	141.4	145.1	149.7	154.5	158.5	163.2
12.5	555	152.9	0.31	7.3	140.1	143.7	147.7	152.6	157.6	162.3	166.6
13.0	547	156.1	0.34	7.9	142.8	146.1	150.3	155.7	161.1	166.4	171.0
13.5	540	159.4	0.36	8.3	145.5	149.0	153.5	159.0	165.1	170.1	175.0
14.0	526	163.2	0.38	8.6	148.2	152.2	156.9	163.1	169.6	174.1	178.7
14.5	514	166.9	0.38	8.6	150.7	155.3	160.9	167.1	173.1	177.4	181.9
15.0	491	170.1	0.38	8.3	154.2	158.8	165.0	170.4	176.2	180.2	183.7
15.5	462	172.7	0.37	8.0	157.5	162.0	167.2	173.0	178.6	182.7	185.6
16.0	427	174.7	0.40	8.2	161.0	164.5	170.0	174.8	180.0	184.6	187.5
16.5	388	176.3	0.41	8.0	162.6	166.7	172.1	176.3	181.2	185.7	189.0
17.0	337	177.7	0.38	6.9	164.7	168.6	173.3	177.7	182.5	186.5	190.6
17.5	312	178.6	0.39	6.8	166.0	169.9	174.0	178.5	183.2	187.5	191.6
18.0	295	179.4	0.39	6.7	167.3	170.5	174.8	179.3	183.8	187.9	192.5

WEIGHT (kg)

Age (years)	No. of boys	Mean	SE	SD	centiles 3rd	10th	25th	50th	75th	90th	97th
10.0	217	32.2	0.36	5.3	24.1	26.5	28.3	31.2	35.2	38.9	42.2
10.5	479	33.6	0.27	5.8	25.7	27.5	29.7	32.8	36.2	40.4	45.1
11.0	542	35.3	0.26	6.0	27.0	28.9	30.9	34.5	38.2	42.6	47.1
11.5	556	37.1	0.27	6.5	27.9	30.0	32.2	36.1	40.5	45.0	50.3
12.0	558	38.9	0.29	6.9	29.2	31.1	34.0	37.9	42.9	47.9	53.8
12.5	555	41.1	0.32	7.4	30.6	32.6	35.5	40.0	45.6	51.2	56.6
13.0	547	43.5	0.35	8.2	31.8	34.4	37.2	42.1	48.2	54.5	61.2
13.5	540	46.3	0.37	8.7	33.5	36.1	40.1	44.6	51.5	58.4	64.4
14.0	526	49.3	0.40	9.1	34.9	38.3	42.8	48.1	55.1	61.5	68.3
14.5	514	52.3	0.41	9.3	36.6	40.8	45.7	51.6	58.3	64.8	70.8
15.0	491	55.4	0.43	9.4	39.7	43.7	49.0	54.5	61.1	68.4	73.9
15.5	462	58.2	0.44	9.4	42.6	46.6	51.9	57.5	63.7	70.4	77.6
16.0	427	60.6	0.44	9.2	45.5	49.8	54.2	59.5	66.0	72.7	80.2
16.5	388	62.7	0.46	9.1	47.5	51.9	56.7	61.5	68.0	74.7	81.0
17.0	337	64.4	0.49	9.0	49.4	53.0	57.7	63.1	70.4	77.7	84.0
17.5	312	65.5	0.50	8.9	50.3	54.5	58.8	64.4	71.6	78.9	84.7
18.0	295	66.5	0.51	8.8	51.7	55.9	59.9	65.4	72.6	79.0	84.9

Table 5. Standards for boys. Height (cm) and weight (kg) from 10.0 - 18.0 years of age.

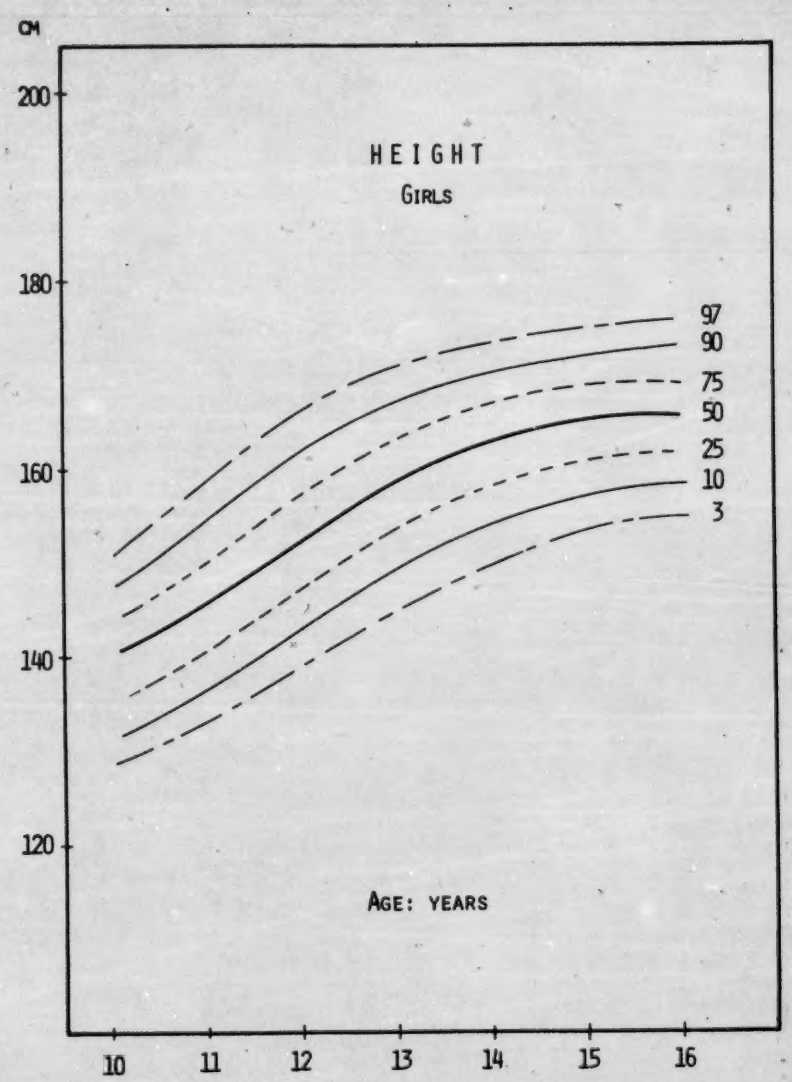

Figure 2. Standards for height. Girls 10.0 - 16.0 years.

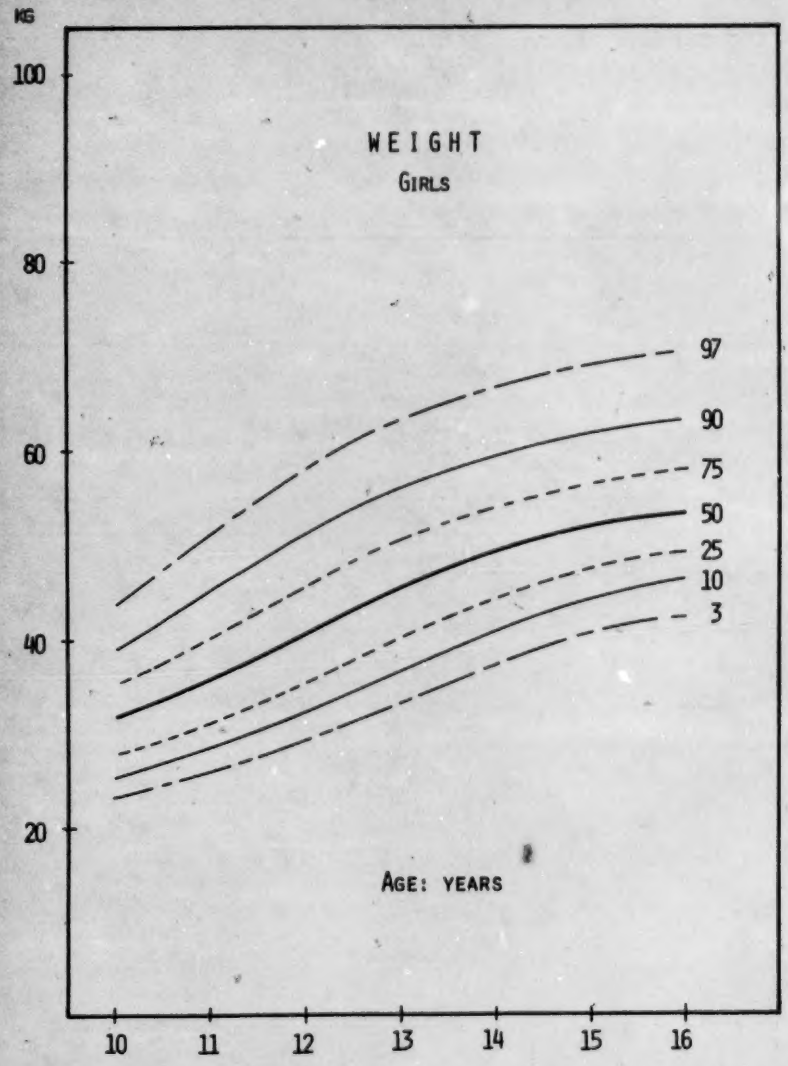

Figure 3. Standards for weight. Girls 10.0 - 16.0 years.

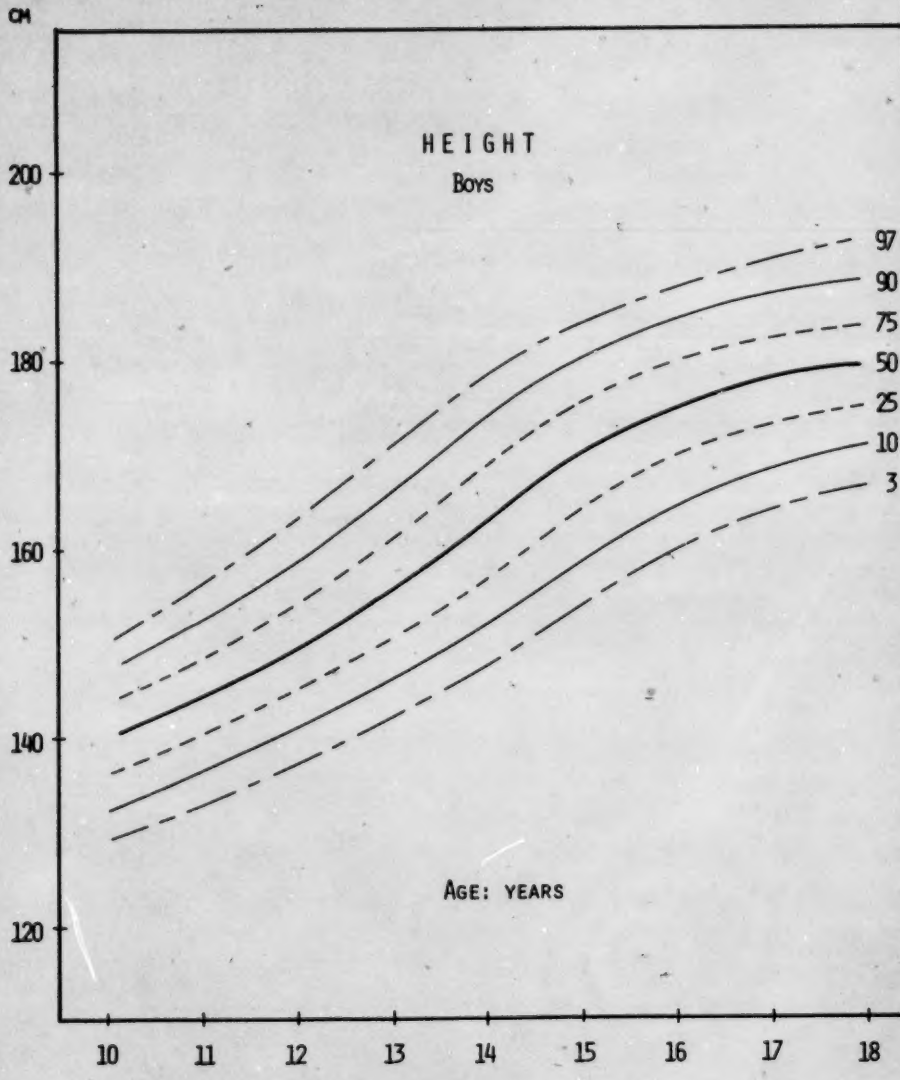

Figure 4. Standards for height. Boys 10.0 - 18.0 years.

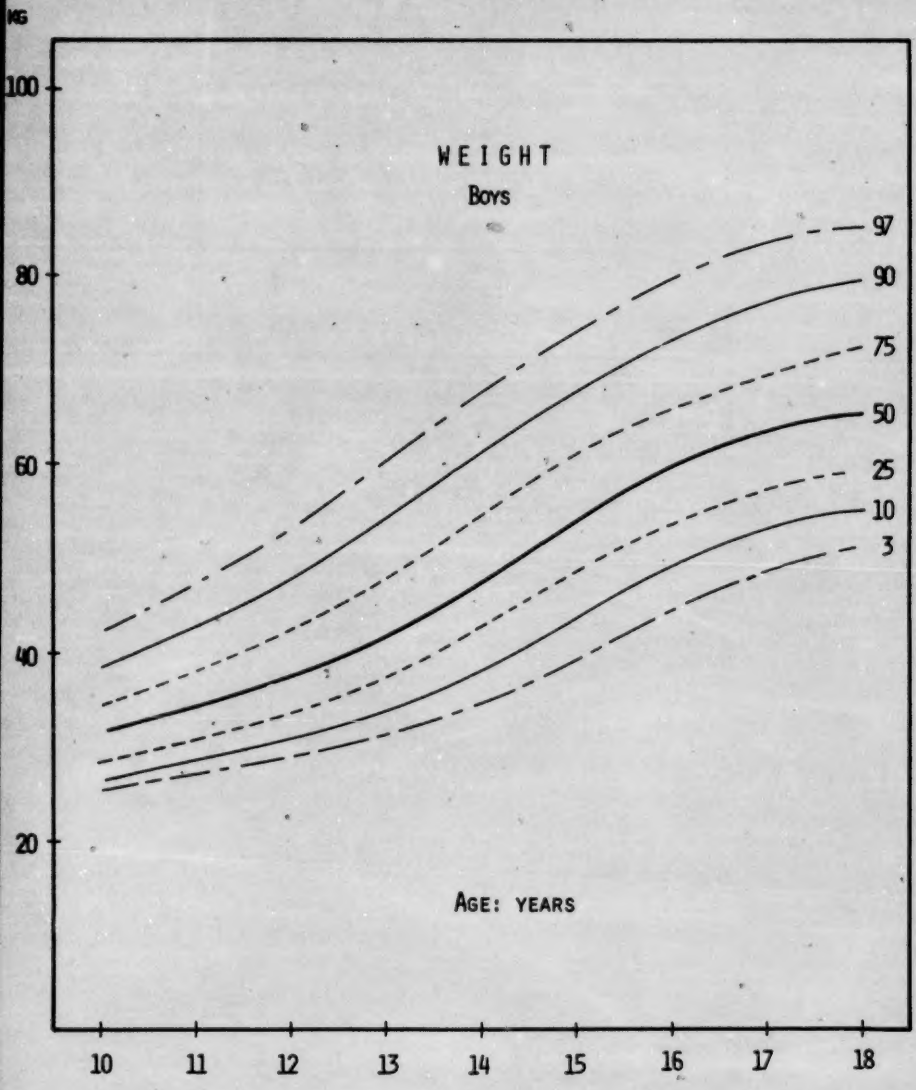

Figure 5. Standards for weight. Boys 10.0 - 18.0 years.

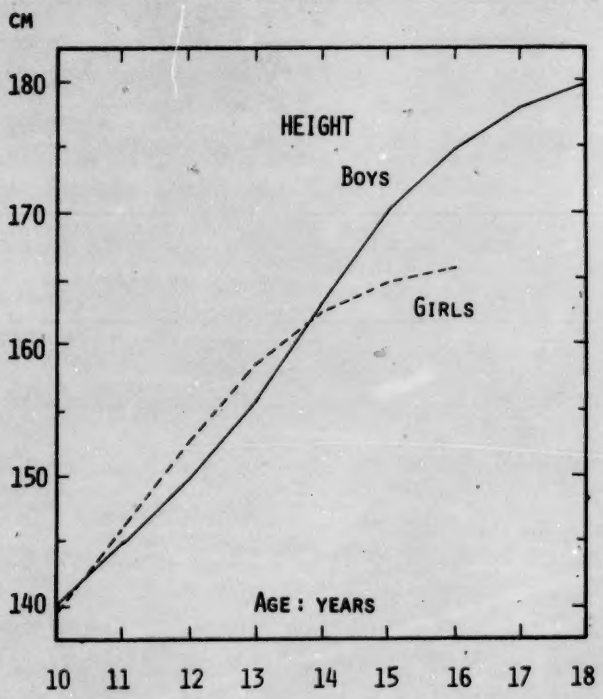

Figure 6. Mean height at successive ages for girls and boys.

Comparisons between girls and boys regarding mean height, mean weight and mean weight/mean height at successive ages are given in Figures 6 - 8. Figure 6 shows that girls on average are taller than boys from 11.0 to ca 14.0 years when the boys surpass the girls for good. At about 12.0 years of age (the mean age for girls' PHV) the girls are about 2.5 cm taller than boys whose average height is about 150 cm at this age. At the age of 14.0 years (the mean age of boys' PHV) boys are almost 1 cm taller than the girls; a gap which at the age of 16.0 has widened to 9 cm in the boys' favour.

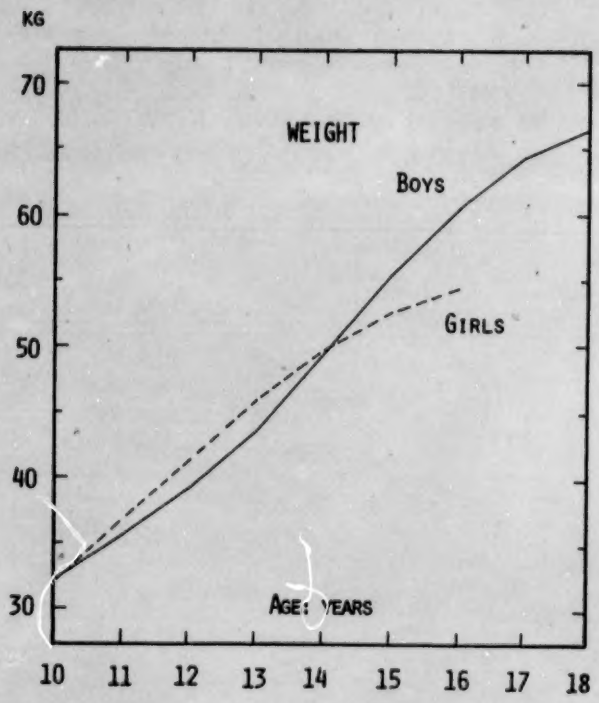

Figure 7. Mean weight at successive ages for girls and boys.

In the same way Figure 7 shows girls' and boys' development in mean weight. The weight curves for both the sexes give a similar pattern to the height development although the crossing-over point between girls' and boys' weight curves occurs about half a year later than for the crossing-over point between girls' and boys' height curves.

Figure 8 shows the mean weights at successive years of age plotted against the corresponding mean heights; for girls from 10.0 - 16.0 years and for boys from 10.0 - 18.0 years. The points in the figure represent successive age classes. (The model for the diagram comes from Hiernaux, 1964). The diagram tells us that

girls up to 13.0 years of age are taller and weigh more than boys of the same age. At the age of 14.0 years boys are somewhat taller than girls but weigh somewhat less. After the age of 14.0 the ratio mean weight/mean height becomes considerably greater for girls than for boys even if the latter are successively both taller and heavier than the girls from that very same age.

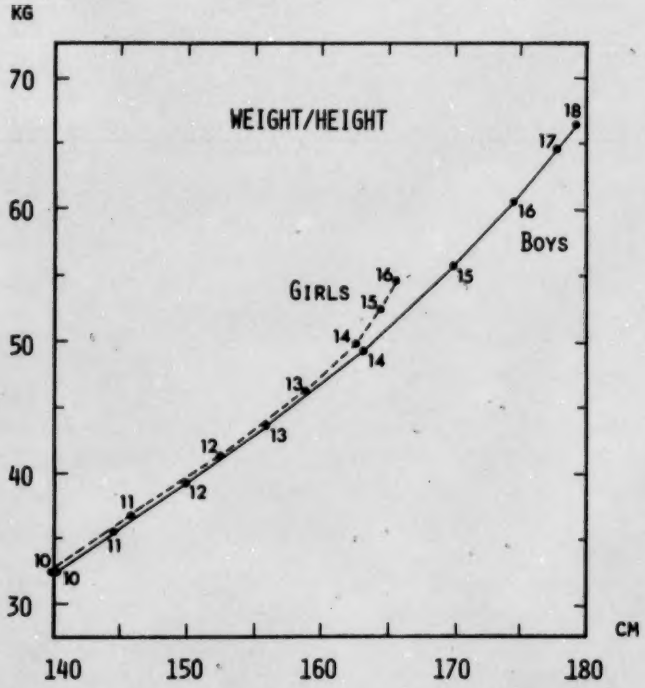

Figure 8. Mean height/mean weight for girls and boys. The points represent successive age classes; for girls from 10.0 - 16.0 years; for boys from 10.0 - 18.0 years.

The *average* ages at which different criteria of physical maturity are reached for girls and boys are presented in Table 6 (from Lindgren, 1975). However, no individual girl or boy fits into the respective "average-pattern".

	Chronological age (years)					
	Girls*			Boys*		
Criteria	Mdn	M	SD	Mdn	M	SD
PHV	11.87	11.91	0.95	14.23	14.09	1.11
PWV	12.35	12.50	1.08	14.47	14.30	1.11
Menarche (S+E)	13.01	13.05	1.03	-	-	-
SSC II	11.46	11.74	0.83	11.96	12.10	0.93
SSC III	12.48	12.54	0.97	13.50	13.48	1.11
SSC IV	13.50	13.43	1.08	14.50	14.39	1.04
SSC V	15.02	14.50	0.98	15.54	15.23	1.05

*Number of cases varies from 259 to 358 for girls; and from 314 to 378 for boys.

PHV peak height velocity; maximum gain in height (cm/year)

PWV peak weight velocity; maximum gain in weight (kg/year)

Meanarche menarcheal age according to primarily *the diary method* (S) and secondarily *the recall method* (E)

SSC secondary sex characteristics rated by pictorial criteria in five stages from the preadolescent (I) to the mature (V) stage. Breast and pubic hair stages were combined for the girls and so were the genital and pubic hair stages for the boys.

Table 6. Average ages at which different criteria of physical maturity were reached for girls and boys (from Lindgren, 1975).

A comparison between boys and girls shows that girls on average are more than two years earlier than boys according to physical maturity with PHV as the criterion. Due to mean PWV age, however, the difference seems to be somewhat smaller than two years between the sexes. The stages in the development of secondary sex characteristics are not comparable between the sexes. Neither are the values or mean ages of SSC II - V easily compared with the values found in other investigations for reasons discussed

by Lindgren (1975, p. 20 - 21).

Quite a large variation in physical maturity exists within each sex. The earliest girls have for instance their peak height velocity (PHV) at 9.5 years and the latest at 15.0 years. The earliest boys have their PHV at 11.0 years while the latest have their's at 16.5 years (paper III, p. 254, Figure 1). The age difference in this respect between the earliest girls and the latest boys is thus about 7 chronological years.

Most of the results from the description of the physical growth for this sample are in accordance with data from other studies during the same investigation period. (For references see paper II and III).

5.2 Comparisons with previous studies
(Question A:2; paper I)

By comparing the results on the physical growth and development of the core sample with the results from investigations conducted in 1883 (Key, 1885) and 1938/39 (Broman et al., 1942) the secular trend has been studied. The results indicate that for height the trend has been continuing from the late 1930's to the late 1960's and during this period was more pronounced for girls than for boys in contrast to the period 1883 - 1939. For boys an analogous trend in weight had happened. A corresponding trend in weight was noted for girls age 10.0 - 14.0 years although less pronounced than for boys. But a trend in the opposite direction was noticed for girls in the ages 15.0 - 16.0 years. Girls of these ages were on average lighter in the late 60's than in the late 30's. Because of a proportionally larger increase in height than in weight the children had become thinner throughout the years - a tendency which seems to have been more marked in girls than in boys during the period 1938-39 to 1965-71. Thus the weight/height ratio was in general more similar for the two sexes in the late 60's than it was 30 years before.

The increase in height per decade from 1883 to the late 60's has according to the data slowed down during the last 30 years in both sexes but somewhat more so in boys. Regarding the differ-

ent criteria of physical maturity; PHV, PWV and menarche; ages of PHV and PWV were not well determined in the earlier studies from 1883 and 1938/39. However, a graphical smoothing of the height and weight velocity curves shown in paper I (p. 252, Figures 7 - 10) as well as inspections of actual data in Key (1885, tables on p. 538, 543, 546 and 548) and Broman et al. (1942, Table 23a, 23b, 24a and 24b) give peak ages; in height of about 12.8, 12.2 years for girls and 15.2, 14.3 years for boys; in weight of about 14.2, 13.1 years for girls and 16.4, 15.0 years for boys. When all these data inclusive of menarcheal age data also from 1886, 1900, 1915 and 1950 (paper I, p. 253, Figure 11) are comprehended with the corresponding data from the present investigation (Lindgren, 1975 and paper II) it seems that the whole process of puberty is passed through at a higher speed nowadays than a hundred years ago.

From about 1880 to the late 1960's girls PHV age has lowered by about 0.1 year/decade, their PWV age by about 0.2 year/decade and their menarcheal age from 1950 by about 0.3 years/decade. The pattern for the boys is somewhat different as the lowering of PHV age from 1883 to 1938/39 seems to be about 0.2 years/decade whereas from 1938/39 to 1969 it has slowed down and amounts to a decrease of less than 0.1 years/decade. The decrease in PWV age, however, seems more steady and amounts to about 0.2 years/decade from 1883 to the present days.

5.3 Physical development related to socio-economic and regional factors

(Question A:3; paper II)

Since the lowering of ages at menarche and at peak height and weight velocities has been attributed mainly to better nutrition and social conditions, the physical development of the children in the present investigation was studied in relation to their socio-economic status defined by father's occupation and/or family income. Also from the social point of view, the variables single parent/two parents and mother working out of home/at home were interesting to relate to the children's physical growth and development.

Concerning the children's physical development no differences

between socio-economic strata (defined by social group and/or family income) were found in mean heights and weights for girls from 10.0 - 16.0 years or for boys from 10.0 - 18.0 years. Regarding weight for constant height, however, girls in social group III hade more weight for given height during puberty than had girls from social groups I and II. When analyzing height, weight and the weight for constant height of children living in homes with single parent/two parent families or mother working out of home/at home no significant differences were found.

Neither were there any differences found between socio-economic strata regarding ages at PHV, PWV and menarche. A thorough after-inspection of the data in paper II (p. 513, Table 4) gave, however, the impression that the time interval between mean PHV age and mean PWV age was successively somewhat greater from social group I to social group III - at least for the girls. However, a reanalysis of the data on the time-differences between PHV age and PWV age did not give any significant differences between the social groups.

The physical development of the children was also analyzed concerning region (North, Middle, and South Sweden) and urbanization level (number of inhabitants) since in the late 30's Broman et al. (1942) found regional or urban/rural differences in height and weight. Results from the present study were, that regarding girls' and boys' height and weight there were no differences between the three main regions, except for girls from Middle Sweden being taller and heavier than girls from the South at the ages 11.0 - 12.0 years and boys from the South being heavier than boys from Middle and North Sweden at the ages 17.0 - 18.0 years. Height and weight did not differ between girls from Stockholm, Göteborg and Malmö. Neither were there any height differences between boys from the three big cities. The weight for these boys differed, however, at the ages 16.0 - 18.0 years so that boys from Göteborg were the heaviest, next were Malmö boys and last or lightest were the Stockholm boys.

Youths from cities and towns in Middle Sweden (except for Stockholm) had their PHV age half a year earlier than the youths from cities and towns (except for Göteborg and Malmö) in the South.

Also PWV age for the girls was about 7 months earlier and for the boys about 5 months earlier in Middle Sweden compared to those in the South. A further analysis (see Lindgren, 1978) of the PHV age in different provinces (Sw. landskap) in Sweden showed that the earliest boys were brought up in the province of Värmland (M = 13.3 years; SD = 1.2; n = 11) and the earliest girls in the province of Södermanland (M = 11.4; SD = 0.7; n = 10). The latest girls (M = 12.4; SD = 0.8; n = 30) and boys (M = 14.4; SD = 1.0; n = 25) were found in the province of Västergötland. As can be noticed from the n's the samples in the different provinces were extremely small so these results should be tested in further investigations on bigger samples.

Girls from Stockholm had their PHV age earlier than girls from Göteborg, but the earliest PWV age occurred in Malmö girls. The time-difference between ages at PWV and PHV for girls as well as boys in Malmö also seemed shorter compared to that for children in Göteborg and Stockholm (paper II, p. 525 - 526, Appendix table 1 and 2). Boys in Stockholm had a PWV which was 1 kg/year less than that of boys from Malmö and Göteborg.

In an analysis of variance for girls' as well as boys' age at PHV significant interactions were found for region times urbanization level. In the South and the North PHV age was earlier the higher the urbanization level but in Middle Sweden the reverse occurred. This kind of interaction was not found for PWV age and was only indicative for menarcheal age.

5.4 Physical characteristics in early, average and late maturers (Question A:4; paper III)

When grouping the children into early, average and late maturers with PHV age as the criterion of physical maturity the following differences in physical growth from 10.0 - 16.0 years for girls and 10.0 - 18.0 years for boys were found. Mean heights differed between the maturity groups from age 10.0 to 14.0 years for girls and from 10.5 to 17.0 years for boys as are shown in Figure 9 and 10.

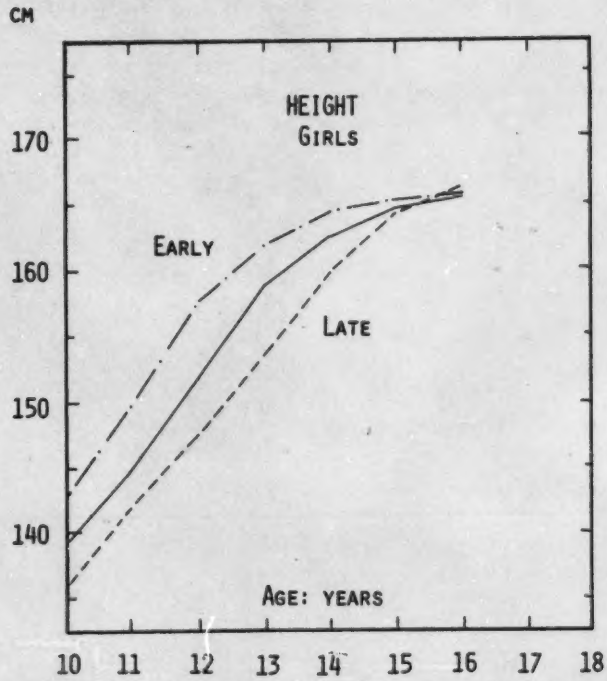

Figure 9. Mean height at successive ages (10.0 - 16.0 years) in girls with early, average and late peak height velocity ages.

Mean weights differed at all ages up to and including 16.0 years for girls and up to and including 18.0 years for boys. Early maturing girls and boys also seemed to have a greater weight for given height at all the investigated ages (paper III, p. 258 - 259, Figure 2 and 3).

The correlation coefficients between ages for various criteria of physical maturity were fairly high (paper III, p. 264, Table 10), so there were, as expected, differences between the maturity groups regarding all the physical maturity measures; PWV age, menarcheal age or SSC IV age. That is, early maturers defined by an early PHV age have also in general an early PWV age,

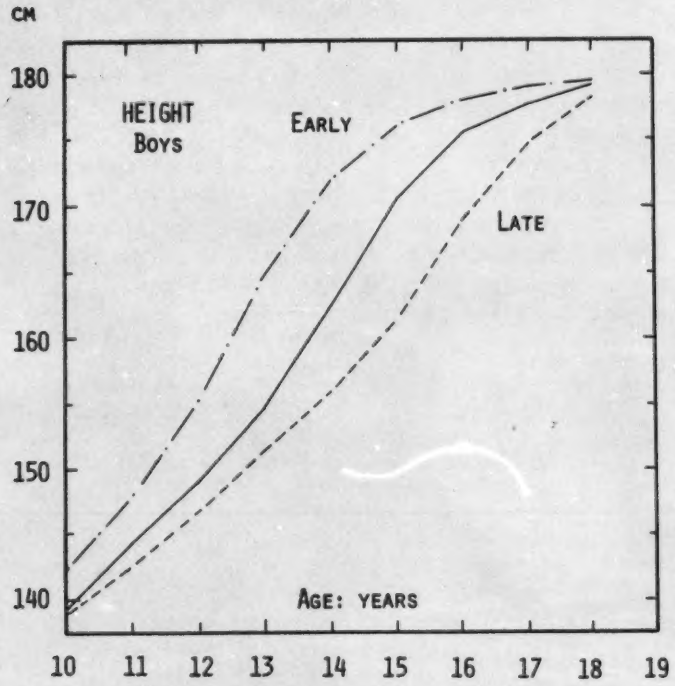

Figure 10. Mean height at successive ages (10.0 - 18.0 years) in boys with early, average and late peak height velocity ages.

and menarcheal age or SSC IV age. Early maturers, especially boys, also have a higher peak (cm/year) in height velocity than have average and late maturers (paper III; p. 262 - 263, Figure 4 and 5). The magnitudes of the weight peak, however, were about the same for early, average and late maturers and amounted to about 7 kg/year for girls and about 9 kg/year for boys.

The time interval (in years) between the various criteria of physical maturity was not of the same length for early, average and late maturers. The average time-differences between PWV and PHV were for early, average and late maturers 0.9, 0.5 and 0.2 years respectively for girls and 0.6, 0.3 and -0.1 years respec-

tively for boys. The intervals between PWV age and menarcheal age for girls as well as PWV age and age at SSC IV for boys, however, were of about the same length regardless of whether PWV was early, average or late and amounted to 0.6 years for girls and 0.1 years for boys. This means that although the early maturing children start (by PHV) their maturity process earlier it will take a longer time for them to reach menarche (or SSC IV) than it does for average and late maturers. Table 7 shows the length of the intervals for early, average and late maturers; between PHV age and menarcheal age for girls; between PHV age and age at SSC IV for boys.

Criteria	Time interval between criteria (years) Early	Average	Late	Total
Girls				
Menarcheal age-PHV age	1.6	1.2	0.7	1.2
Boys				
SSC IV - PHV age	0.7	0.3	-0.2	0.3

Table 7. Time intervals (years) between menarcheal age and PHV age in early, average and late girls and between age at SSC IV and PHV age in early, average and late boys.

From PHV age it took more than twice the time for early maturing girls to reach menarche compared to late maturing girls. In the same way early maturing boys had more than twice the time from PHV age to reach SSC IV compared to average maturers. Late maturing boys had their SSC IV age -0.2 years *prior* to their PHV age. The overall impression was that the maturity process due to the criteria used in the present study *started earlier* but was *more spread out* in time for early maturers and *started later* but was *less spread out* in time for late maturers.

5.5 Spurts in physical and mental growth
(Question B:1; paper IV)

The relationship between physical and mental growth was studied by investigating whether a mental spurt analogous to the height spurt occurred during adolescence. Girls and boys of the core sample were grouped into early, average and late maturers according to physical maturity defined by the child's distance (in years) from its PHV age at the time the child was tested in mental performance. Repeated measurements were conducted once a year from grade 3 to 7 inclusive (10 - 14 years) by means of a mental arithmetic test (the KUP-test). Gain/year in mental performance (defined by *gain in correctly solved items on the KUP-test between two successive years*) and level of performance each year (defined by *number of correctly solved items*) were analyzed over all the grades - by sex and by maturity groups within sex. The analysis was made in both a pure and a mixed longitudinal way, testing the following general hypothesis: *Peak height velocity is accompanied by a spurt in mental growth during puberty.*

Predictions from this hypothesis were that:

a) early, average and late maturers would have their mental spurt (maximum gain/year in mental performance) in the same successive order as their height spurt (maximum gain/year in height, PHV)

b) since girls have their PHV on average about two years prior to PHV for boys, girls would also have their maximum gain/year in mental performance prior to boys'.

As a consequence of these predictions the level of mental performance would then rise earlier in a spurt manner and would also be higher (at least temporarily) the earlier the PHV age.

Pure longitudinal analysis (all children in the sample having performed the KUP-test in every grade,3 through 7).

An indicative interaction was found for gain/year in mental performance between grades (3 - 4, 4 - 5, 5 - 6 and 6 - 7) and girls' maturity groups (early, average and late). Early maturing girls seemed to have a prolonged spurt from grade 4 to 6 - and

average maturing girls had also a spurt from grade 4 which, however, ended already in grade 5. Late maturing girls seemed to have one preadolescent gain peak from grade 3 to 4 but still another from grade 6 to 7. The interaction between grades and boys' maturity groups concerning gain/year in mental performance was not significant. On the other hand early maturing boys had a marked gain in performance from grade 5 to grade 7 and gained more than average and late maturing boys during the investigation period.

A graphical comparison between girls' and boys' annual gain in performance gave the predicted picture (paper IV, p. 18, Figure 4). Girls had their maximum gain/year in performance from grade 4 to grade 5 (plotted at age 11.9 years) and the boys had their maximum gain/year at least two years later (at age 13.9 years). These ages of maximum gain/year in mental performance coincided very well with the mean PHV ages for the girls (11.8 years) and the boys (13.9 years). But the overall analysis did not reveal any significant differences concerning gain/year in mental performance between either the sexes or the grades. Neither was there any significant interaction between these two factors.

When testing the differences in mean level of performance over grades between early, average and late maturers no significant differences were found either for the girls or the boys. For boys there was, however, an indicative interaction between maturity groups and level of performance which was due to the early maturing boys being the poorest performers in grade 4 but the best performers in grade 7 (paper IV, p. 17 , Figure 3).

The comparison between girls' and boys' level of performance over all grades indicated that girls during the investigation period (10.0 - 14.0 years) were superior to boys. The samples of children used in this pure longitudinal analysis were small, compared with the mixed longitudinal samples. This might explain the fact that the observed differences seen in the graphs were not statistically significant. Furthermore the social group distributions for girls and boys were not quite representative for urban children. Social group III was overrepresented in the girls' group and underrepresented in the boys' group, which

had negative (for girls) and positive (for boys) effects at least on *level* of performance.

Mixed longitudinal analysis (the children having performed the KUP-test at least in one grade during the investigation period)

In the mixed longitudinal analysis the social group distributions were more representative at least for the girls. Among the early and late maturing boys, social group I + II was still somewhat overrepresented.

The analysis of gain/year in performance over all grades gave the following results. From grade 4 to 5 early and average maturing girls had a significantly higher gain in performance than had late maturing girls. From grade 5 to 6, however, late maturing girls gained more in performance than early and average maturers. For boys, gain/year in performance over the grades did not differ between the maturity groups.

Girls seemed to have their maximum gain in performance between grade 4 and 5 while boys during the investigation period seemed to have their's between grade 6 and 7.

As was expected, late maturing girls were inferior to early and average maturing girls in level of performance during the investigation period. For boys, however, there was no difference in level of performance between the maturity groups from grade 3 to 7 inclusive. The comparison between girls' and boys' level in performance over grades showed that girls were superior to boys during the investigation period, especially in grade 5 and 6.

Social background (defined by father's occupation) had a great impact on the children's level of mental performance, when measured by this kind of test. An approximation was made concerning the relative impact from physical maturity and social background on level of performance of the KUP-test. This approximation was expressed as the ratio between the mean difference in test scores for early versus late maturers and the mean difference in test scores for social group I + II versus social group III. The ratio fluctuated over the grades 3 through 7.

Physical maturity seemed to have the greatest impact in grade 5 (age 12) for girls and in grade 7 (age 14) for boys. On average the impact of physical maturity in relation to social background on level of mental performance was (by this rather rough approximation) about one fifth for the samples of girls and less than one tenth for the samples of boys during the whole investigation period.

5.6 School achievement and mental ability in physically late and early maturers related to social background. (Question B:2; paper V)

Some of the results from the study of the relationship between physical and mental spurts during the age period 10 - 14 years indicated that physical maturity had an impact on level of mental performance. This was mainly found for the girls and seemed somewhat more pronounced for girls in social group III than in social group I + II.

In addition to the KUP-test, which the children performed once a year from grade 3 to grade 7 inclusive, some other achievement and mental ability tests were performed during this period. The children were given standardized achievement tests in Swedish in grade 3 (Sw_3) and Mathematics in grade 3 and 6 (Ma_3, Ma_6). In grade 5 a mental ability test (DBA_5) was given consisting of three subtests measuring verbal ability (DBA_{a5}), logical inductive reasoning (DBA_{b5}) and clerical speed (DBA_{c5}). Children's marks in Swedish ($Mark_{Sw6}$), English ($Mark_{Eng6}$) and Mathematics ($Mark_{Ma6}$) were collected from the autumn term in grade 6.

It was now of interest to analyze the test scores from the latter tests according to an early and late maturation (still defined by "PHV age distance" at the time of testing) controlling for social background (defined by father's occupation). The children's test scores were thus analyzed according to the following questions:

. Are physically early maturers superior to late maturers in school achievement and mental ability at the ages of 10, 12 and 13?

. Are there any differences in this respect concerning sex and social background?

The results obtained from the analyses were as follows:

The only test out of Sw_3, Ma_3, DBA_5 and Ma_6 on which early maturers were superior to late maturers was the mental ability test in grade 5 (DBA_5) and this result was obtained only for the girls. Early girls seemed also in grade 6 to be superior to late girls regarding marks in Swedish and English. Early boys were superior to late boys only on two subtests in grade 3, namely "Punctuation" (subtest in Sw_3) and "Problems" (subtest in Ma_3).

Social background played a major role for the children's performance on almost all tests at the investigated ages - as it did on the KUP-test. For girls significant social group differences were found on Sw_3 and DBA_5 but not on Ma_3 and Ma_6. For boys significant social group differences were found on all these tests. Regarding the marks in Swedish, English and Mathematics given to the children in grade 6 significant differences between social groups were found for both boys and girls. These differences were for girls more marked in Swedish and English than in Mathematics while the opposite was noticed for the boys.

For some of the tests an interaction was found between maturity group (early, late) and social background (social group I + II, social group III), e.g. early maturers scored higher than late maturers in social group III while no difference between early and late maturers was noticed for social group I + II. This interaction was mainly found for verbally loaded tests and at the investigated ages was somewhat more pronounced for the girls than for the boys. In social group III early girls were superior to late girls regarding the standardized achievement test in Swedish (grade 3) and the marks in Swedish and English (grade 6). Early boys scored higher than late maturers within social group III only on the verbal subtest DBA_{a5}. In social group I + II there were no significant differences in mean scores between early and late maturers on any of the tests or the marks - either for girls or boys.

6. GENERAL DISCUSSION

Findings from the present study show that Swedish schoolchildren of today are larger and grow to maturity more rapidly than did children a hundred years ago. This secular trend has been observed in practically all industrialized countries. Swedish data, however, seem to be the most comprehensive during the last century.

Possible causes of the trend have been suggested like better nutrition and better general health but also an increased degree of outbreeding where dominant genes (for tallness or early maturation) through the years produce successively taller offsprings (heterosis). In the industrialized countries this increased outbreeding has accompanied the urbanization process (cf. Tanner, 1978, p. 150).

Earlier as well as more recent sources of various kinds have documented the efforts during the last century to improve the physical health of Swedish children - before and during their school period (e.g. Jonsson, 1928; Svedenius, 1945; Petersson, 1975; Offical State Reports, 1976).

In the Official State Reports (1976) it is reported that already in 1830 the first school doctor in Sweden was employed and soon afterwards successors appeared. The pioneer school doctors were not paid for their work at the school and their task was presumably to treat the poorer pupils if requested. The School Committee convened in 1882 (in which professor Axel Key was the medical expert) suggested that every secondary school (Sw. läroverk) should have a school doctor and this was carried through in 1892. But the suggestions were meant only for the secondary school whereas the elementary school (Sw. folkskola) founded in 1842 had no medical support for the children. Not until 1919 was the first school nurse employed for some elementary schools in Stockholm on the initiative of some teachers.

In 1943 - when the first chief medical officer was appointed at the National Board of Education - the outlines for a comprehensive school health service were suggested. One of the proposals

was that for every school a doctor and a nurse should be responsible for the children's health. The outlines were passed by the Parliament in 1944 and from this decade a national health program was successively carried through by various reforms concerning not only the school health service but also the health care of infants and preschool children (Petersson, 1975). As an example special school meals for the children were suggested (Svedenius, 1945) and today all schoolchildren get their lunch at school provided by the local authorities.

Standards in height and weight to evaluate the physical growth of schoolchildren were obviously used already from 1928 when the teachers were provided a small "handbook" (Jonsson, 1928). In this "handbook" standard tables for height and weight were given based on data for elementary schoolchildren in Copenhagen reported by doctor Poul Hertz. Swedish standards were constructed in the 40's by Broman et al. (1942).

In addition to the reforms concerning the children's physical health, reforms in the educational area were pleaded for (Isling, 1973; Richardsson, 1977). In 1918 a suggestion was on hand for uniting the two parallel and independent school systems - the elementary and secondary school systems. The reasons for the proposal were social, pedagogical and economical (Isling, 1973, p. 51 - 52). The comprehensive school system that we have today (Sw. 9-årig grundskola) was, however, not created until 1962. Meanwhile the compulsory schooling in the elementary schools - which from the beginning was comprised of 6 years (at most) - was successively extended by another two years.

The brief and selective historical review above was made merely to give some of the social context in which about four generations of children have been growing and a secular trend in physical growth has been observed as is illustrated in Figure 11 and 12. Figure 11 and 12 comprehend graphically the summarized results for girls and boys given in section 5.2 (p. 35). With a reservation for the possibility of not having estimated PHV and PWV ages in the older investigations quite exactly, the figures clearly show that - apart from secular trends in ages at PHV, PWV and menarche - the rates of the trends in menarche and PWV

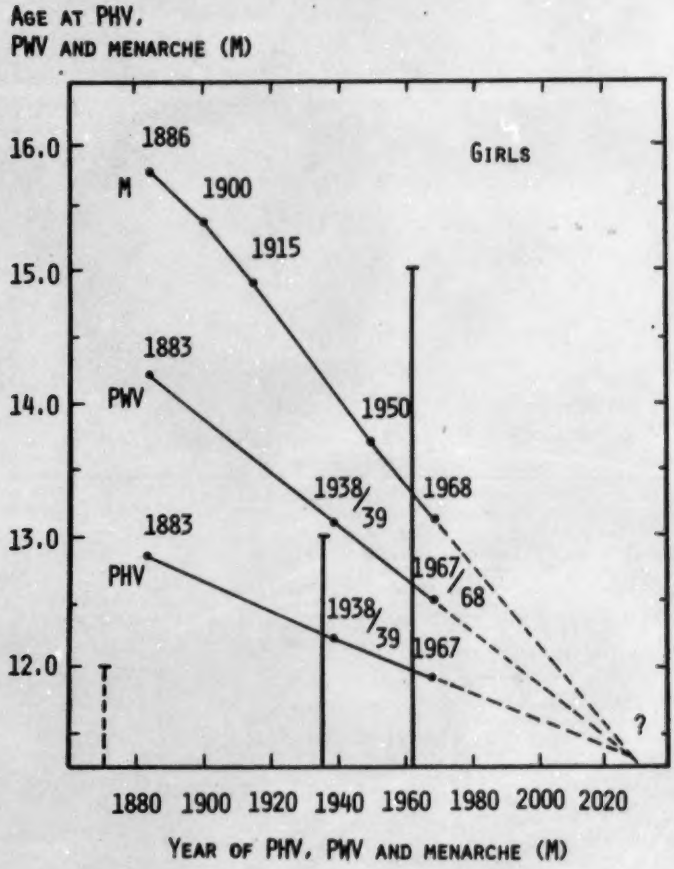

Figure 11. Secular trends in ages at PHV, PWV and menarche for Swedish girls. PHV and PWV age data; for 1883 from Key (1885) estimated from his tables on p. 546 and p. 548; for 1938/39 from Broman et al. (1942) estimated from their Tables 23b and 24b; for 1965 - 71 from papers I and II. The vertical lines give ages up to which school is compulsory.

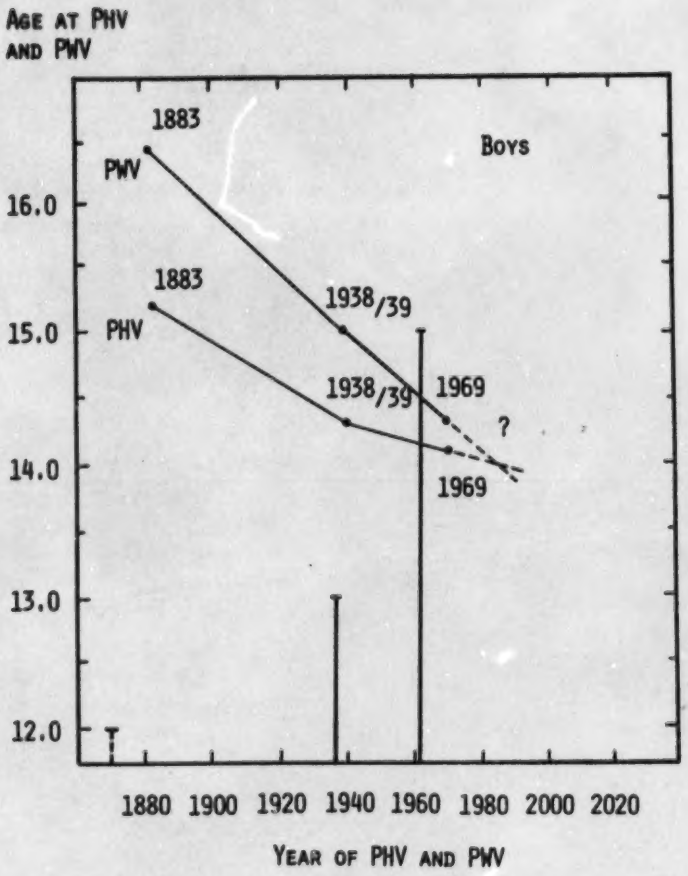

Figure 12. Secular trends in ages at PHV and PWV for Swedish boys. Data for 1883 from Key (1885) estimated from his tables on p. 538 and p. 543; for 1938/39 from Broman et al. (1942) estimated from their Tables 23a and 24a; for 1969 from paper II. The vertical lines give ages up to which school is compulsory.

have been faster than for age at PHV. So the children do not only reach puberty earlier but also pass it more quickly today than before. *If* these trends are still continuing with the same rate the hypothesis would be that girls on an average will have their PHV, PWV and menarche at about the same time in the year of 2030 ! The trend in age at PHV for boys is not as linear as for girls. An explanation could be the higher mortality rate for boys in the 1940's compared to that for girls (Petersson, 1975, p. 16), thus an effect of selective survival (cf. also Ljung et al., 1977). There is, however, no evidence that it was the late maturing boys in the 1940's, who died young.

The rate of the trend for PHV age has been slower than for PWV age and menarche during the last hundred years. It seems possible that the trend in PWV age to a greater degree than the trend in PHV age has been influenced by better standard of living (general health and nutrition). The slower trend in PHV age might be explained by its comparatively higher genetical control. The part-independence of the trends might be supported by the findings; that for early maturers (defined by an early PHV age) it takes a comparatively longer time to reach PWV age than it does for late maturers (see p.39). In addition the rate of the trend in PWV age seems to be independent of sex as the decrease of about 0.2 years/decade during the last hundred years is the same for both girls and boys (see p. 35). Menarcheal age seems connected to both PHV age and PWV age or rather the factors controlling them; to PHV age by the similar results when analyzing the variances regarding PHV age and menarcheal age respectively for regions times urbanization level (see p. 37); to PWV age as the mean time interval between menarcheal age and PWV age is of the same length regardless of whether PHV age is early, average or late (see p. 40).

There has been a discussion about whether the secular increase in height has stopped or not in Sweden (Letters to the editor, 1978). By comparing conscript data on height during the last five years it has been claimed that the trend is continuing. However, Swedish conscript data of today are not as representative as they used to be; mainly because of the great loss of individuals who are postponing their enrolment for various reasons (cf.Otto,

1976, p. 15) together with the fact that PHV age for the conscripts (aged 17 - 19 years) is not controlled for. Mean PHV age differs between regional areas and urbanization level so these factors must also be controlled for when estimating mean height of the conscripts since their heights at the time of enrolment still might be linked to an early, average or late PHV age (see p.39). The differences found in mean height by Broman et al. (1942) between children in Stockholm, Malmö and Östergötland and by Samuelsson (1971) between urban and rural children in the North of Sweden, could in part be explained by differences in mean PHV ages (cf. Tanner, 1978, p. 151 - 152).

For the present sample of urban schoolchildren no differences between socio-economic strata were found either for ages at PHV, PWV and menarche or heights and weights during the investigation period. So far as can be ascertained this is the first *nationwide* survey in which no differences in physical growth between persons of different socio-economic status have been found. By reference to Dr Wallø, Tanner (1977, p. 23) reports that in Oslo too no differences were found in 1970 between children of different social groups (defined by father's occupation) as had been documented in the Norweigan Official Statistics.

Even if no rural children were represented in the present sample the low correlation coefficient (r = 0.044) between social group and height reported by Otto (1976, p. 51) for an annual population of Swedish conscripts born in 1953 indicates that *if* there are social group differences in height within the rural population they might not be big. Conscript data were available for the present sample as well (Aronsson and Lindgren, 1979). It might be of interest to know that the only significant correlation coefficients that were found between social group and a variety of physical and physiological measures (including height; r = 0.02) was handgrip (r = 0.19) and armbending (r = 0.12). These relationships, however, might mainly be the effects of the comparably high per cent of boys from social group III leaving school after grade 9 for manual jobs (cf. p. 57).

There were in contrast to previous Swedish investigations (Key, 1886; Broman et al., 1942) no differences found in children's

height (or PHV age) between different socio-economic strata in the present study. One might wonder if, apart from an increasingly better standard of living especially among the lower social groups, an increased social mobility also has contributed - at least in urban areas. *From all that has been said we still can not talk about causes and effects but rather about societal changes and a secular trend which occurred simultaneously.* Nevertheless there *are* reasons for replicating this study in the year of 2000 (or why not in 1980 as the present data by now are getting quite old) just to see if in spite of nonexistent socio-economic differences the secular trend has continued (cf. van Wieringen, 1978). This future study should if possible be carried out on bigger samples, including especially rural children, and use a multifactorial design. In most parts it could follow the investigation recently conducted on Cuba (Jordan et al., 1975).

Let us turn back to the Figures 11 and 12 (p. 48 and 49) to take a look at the increasing length of compulsory schooling and at the same time the decreasing ages at PHV, PWV and menarche. Clearly there are in these two respects opposite trends and several authors have discussed the different needs in youth of today (compared to children of the past) because of their earlier maturation (Desjarlais et al., 1975, p. 324; Husén, 1979). The children's social maturation is very much affected by the special attitudes to youngsters held by school and the rest of society. Therefore it has been argued that the organisation and the subject content of the compulsory schooling must meet the new needs from the youth of today, in order not to frustrate their urge for social maturation and natural need to be treated like grown-ups (Hansson and Lindgren, 1977). Otherwise the society might get the queer and problematic combination of "early maturers (in physical growth) and late developers (in social development)".

Another aspect to consider is the children's shorter pubertal process which also might contribute to the "problems" in teenagers of today.

From the ancient to the present days the relation between body and soul or physical and mental growth has interested philoso-

phers as well as educational psychologists (see e.g. Muuss, 1957; Kohen-Raz, 1977) and yet so comparatively little and weak evidence for its existence has been found. The present study of analogous spurts in physical and mental growth gave evidence although not very strong and not directly for the hypothesized relationship between physical and mental development. The findings raise, however, the whole question and hypotheses *how* the connection works.

If the physical growth spurt (defined by PHV age) is accompanied by an analogous mental growth spurt; it means that maximum gain in height (cm/year) has a corresponding maximum gain in mental test scores (gain in test scores/year). Then the general lowering of PHV age (resulting in successively taller children at the same chronological age during the years) would in company have a corresponding and general lowering of age for the mental growth spurt (with successively higher test scores at the same chronological age during the years). Thus the analogous spurts in physical and mental growth might be a possible link and an indirect evidence for the relationship between the parallel secular trends in height and mental ability. It might then not be height *per se* that is related to mental ability but rather physical maturity (defined by PHV age).

This hypothesis is supported when looking at the correlations between scores on the KUP-test on one hand and height and "PHV age distance" on the other from grade 3 through 7. The correlation coefficients fluctuate over the grades but the patterns for height v. test scores and "PHV age distance" v. test scores respectively are similar. The correlation coefficients are somewhat higher for height v. test score than for "PHV age distance" v. test score which probably is an effect of the higher reliability of the height measurements.

For boys at the enrolment (17 - 19 years) the correlation coefficients between test scores on the IC-test versus height and "PHV age distance" were $r = 0.11$ and $r = 0.07$ respectively. Compared to the correlation coefficient of $r = 0.22$ between height and test score for a representative group of 20 year olds re-

ported by Husén (1951) it is for the present sample lower.(Otto, 1976 has reported a correlation coefficient of about the same size; r = 0.095). An explanation for this might be that a former spurious social group effect on height is no longer present. On the whole these correlation coefficients between height and mental ability are very low which means that a very large portion of the respective variances remains unexplained.

In the present study a rather crude measure of physical maturity (PHV age) was used even if it is regarded by e.g. Ausubel (1977) as one of the most reliable. The cognitive growth of the child is most certainly not directly governed by the growth in height but rather with a related brain growth which does not neccessarily mean quantitative change (in size and weight) but qualitative change or maturation. During adolescence the variation of the ages at which maximum height growth occurs vary between and within the sexes. *If* a related spurt in brain growth occurs the ages at which it occurs would vary accordingly. Tanner (1961) claims that:

> "Large individual differences occur in the rates of maturation of the skeleton, in the growth to maturity in height, and in every other aspect of growth about which we know anything. It would be quite astonishing if they did not equally occur in the development of the brain, and we have every reason to suppose they do." (op.cit., p. 92)

Independent pieces of research from different subject areas point in the direction that the relationship between cognitive and physical growth through "physiological links" might exist (see further the discussion part in paper IV).

An interdisciplinary approach with the "missing physiological link" (or links) taken into consideration would be the next step wanted in this area of research. In addition a combination of quantitative and qualitative tests measuring mental or cognitive growth should be used. The qualitative tests might be based on Piaget's theory of cognitive growth (cf. Bergling, 1974; Sandgren, 1974). Furthermore the investigation period should preferably cover the whole range of adolescent variability in physical spurts thus according to Malina (1974):

"the age range 8 to 19 years in girls and 10 to 22 or 23 in boys must be considered." (op.cit., p. 117)

What does it mean to be physically an early or a late maturer at school through the grades investigated in the present study? If PHV age is used as the criterion the ranges in physical maturity between the earliest girls and the latest boys can be 7 chronological years within the same grade. With regard to performance on various achievement tests the relationship to physical maturity is overridden by the heavy effects of social background and/or sex. Together with the latter factors physical maturation interacts in such a way that during the age period 10 - 14 years early maturing girls scored higher than late maturing girls within social group III while a slightly opposite trend or no differences were noticed for girls in social group I + II. This interaction was mainly found for verbal achievement and was somewhat more pronounced for girls than for boys. The possible explanation for this finding could be that late maturing girls as well as late boys from social group I + II compensate for their late maturation by the verbal training they get at home *and/or* maybe early maturers have a comparatively lower motivation than late maturers from social group I + II when taking achievement tests of the kind used in this study. In addition late maturers in social group I + II might get very much extra parental "support" through the parents' very high demands on good performance at school (Andersson, 1979).

The analyses of the results on the mental ability test DBA given in grade 5 and the KUP-test given from grade 3 through 7 for early and late maturers did not give the same pattern as for the achievement tests. On these tests social background and physical maturity rather seemed to have additive effects so that early girls from social group I + II were the best performers and late boys from social group III were the poorest performers.

Late maturing boys from social group III were the poorest performers on almost all the tests given. One might wonder how these boys perceive their time at school! What kind of selfperception and self-esteem do they develop during schooling? Apart from being poor achievers on tests they will probably also have

a low status in the (for boys so important) field of physical activities (cf Tanner, 1978, p. 85). There were only few data available for the present sample that could give some information about these questions(Ahlgren and Lindgren, 1979). But conscript data on the length of formal schooling at the time of enrolment (age 17 - 19 years) were collected for the boys. Thus it was predicted that late maturing boys to a lesser extent would continue their formal schooling than would early maturers and especially so within social group III (cf. Douglas and Ross, 1964). Figure 13 (based on data from Lindgren, 1979) shows the percentage of late an early maturing boys within social group I + II and social group III respectively which at the time of enrolment had chosen longer formal education (defined by senior high school and/or university).

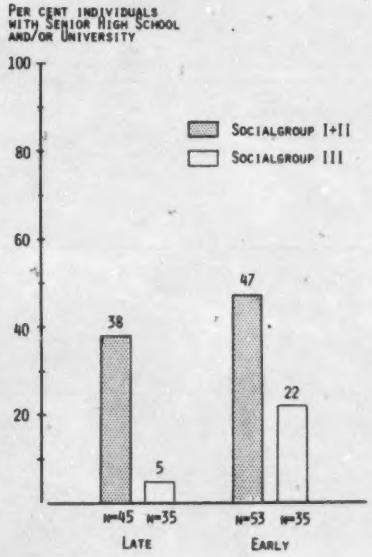

Figure 13. Per cent of late and early maturing boys within social group (I + II), III which at the time of enrolment (age 17 - 19 years) had chosen longer formal education (senior high school and/or university). Data taken from Lindgren (1979).

The most obvious result seen in Figure 13 is that a significantly higher ($p < 0.001$, chi^2-test) percentage of boys from social group I + II enters senior high school and/or university compared to boys from social group III. The long term effect with regard to adult earnings of this usual result has been analysed by for instance Fägerlind (1975). The other striking result seen in Figure 13 is that amongst social group III a significantly smaller proportion of the late maturers than early maturers had entered senior high school and/or university ($p < 0.05$, chi^2- test). In social group I + II there was a similar but much weaker trend (statistically insignificant). Thus to the educational handicaps listed by Emanuelsson (1974) we can add another; late physical maturation, which, however, only concerns boys in social group III.

Yet, it must be mentioned that for this social group there was no difference in mean test scores between early and late maturing boys on the IC-test performed at the enrolment (Lindgren, 1979). So the late maturers' intellectual handicap during the adolescent growth period might have been overcome by a mental spurt or at least a "catch up" some time later in adolescence.

And what about the further education of the early and late maturing *girls*? Unfortunately no data on this topic were collected for them. But a follow up of the core sample in the present study is planned when among other things data on further education will be collected for the young women as well as the young men.

Finally, there are especially *two* important things that should be said about the findings from the present study and their theoretical and practical implications on education.

The *first* one has been expressed by Kohen-Raz (1977):

> "Although exploring the linkage between physical and mental growth is of considerable theoretical importance and likely to stimulate interdisciplinary research and lead to interesting discoveries, its *practical* implications, including selection procedures, possible revalidations of testing instruments, educational streaming, segregation of the sexes, and the revision of curricula, must be considered with great caution." (op.cit., p. 102)

The *second* and probably the most important one, said with the words from Tanner (1978):

> "Little can be done to diminish the individual differences in children's tempo of growth, for they are biologically rooted and not significantly reducible by any social action. *It therefore behoves all teachers, psychologists and doctors to both be fully aware of the facts and alert to the individual problems they raise.*" (op.cit., p. 86, my italics)

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